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# STRESS TOLERANCE INDICES OF MAIZE HYBRIDS IRRIGATED WITH SALINE WATER

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***ABSTRACT***

***Salinity is one of the major abiotic stresses affecting plant growth and development as salinization of cultivated land is increasing globally due to saline water irrigation. There is a considerable variation in salinity tolerance of maize genotypes hence selection of tolerant maize hybrids to saline water irrigation is of great significance in utilising poor quality water for irrigation. The present study was conducted to identify the tolerance of maize hybrids for saline water irrigation under green house condition. Six maize hybrids were chosen and irrigated with saline water having varied inherent salinity levels (0.6, 3.2, 4.8, 6.7 and 8.9 dSm$^{-1}$) and grown in a clay loam soil for 30 days. Considerable variations were observed in the plant growth attributes of maize hybrids at different salinity levels. Increasing levels of irrigation water salinity decreased the plant growth attributes, dry matter production and stress tolerance indices of all the maize hybrids. However the hybrid CO6 registered higher DMP and better stress tolerance indices. Highly significant and positive correlation between DMP and different stress indices were observed except TOL and among these indices stress tolerance index and DMP stability index has obtained highest $r^2$ value ($r^2$ = 0.92 and 0.90) than mean productivity, geometric mean productivity stress stability intensity for better prediction. It could be implicated in selection of irrigation water salinity tolerant maize hybrid for further development of management strategies.***

***KEYWORDS: Saline Water, Maize Hybrids, Growth Attributes & Stress Tolerance Indices***

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**Original Article**

## INTRODUCTION

Profitable agriculture in arid and semi-arid regions is mainly dependent on the fair availability of good quality irrigation water. Fresh surface water supplies in these areas are gradually becoming short to meet the crop water requirement. To augment the inadequate water supplies use of poor quality ground water is imperative. Unfortunately, the major portion of this water (75%) is unfit for irrigation due to variable amounts of ions [Malik et al., 2007].

Continuous and prolonged use of saline water induced salination of soils and greatly hampers the growth of most agronomic crops [Singh et al. 1992]. Utility of poor quality water is possible only either through reclamation or by making the plants physiologically adapted to saline environment. To make the plants best suitable for saline water agriculture, it is essential to study the physiological behavior of plants under the saline water irrigation. Maize (*Zea mays L.*) is an important cereal crop of the country and is grown for fodder and grain

purposes. It is a moderately sensitive to saline water irrigation showing 50 % reduction in yield at ECiw 3.6 dS $m^{-1}$ [Ayres and Westcot 1985]. According to a report maize is sensitive at early stages but could withstand at later growth stages to saline water irrigation [Shirazi et al. 1971]. Sufficient work does not seem to have been focused on the physiological behavior of maize to saline water irrigation, since most of the research has been centered on salt build up in soils and their subsequent detrimental effects on growth and yield. In the present investigation, fresh biomass production, plant growth attributes and stress tolerance indices such as mean productivity, geometric mean productivity, and stress tolerance index were computed to determine the tolerance of maize hybrids against irrigation water salinity.

## MATERIALS AND METHODS

A pot experiment was conducted with six maize hybrids (CO 6, CO 7, CO 8, CO 10, NK 6240 and 900 M gold) coupled with five irrigation water salinity levels ($EC_{iw}$ : 0.6, 3.2, 4.8, 6.7 and 8.9 $dSm^{-1}$) on a clay loam soil. Pots of two kilogram capacity was chosen and filled with one kilogram of processed soil and irrigation was given at alternate days with water having different levels of EC. All the maize hybrids were sown in the pots and one plant per pot was maintained. Nutrients were applied basally as per fertiliser recommendation and the crops were grown upto 30 days and harvested. Plant growth attributes such as plant height, root length and dry matter production were recorded. Harvested plant samples were washed thoroughly with distilled water and dilute HCl to remove the adhering soil particles and other contaminants in the roots, air dried and oven dried at $65^0$C for two days to estimate the dry matter production.

Based on the dry matter production, stress and productivity indices were computed for different EC level of the irrigation water to identify the salinity tolerance of maize hybrids and the data was analyzed with factorially completely randomized design using three replicates at $p = 0.05$. The correlation between different indices was analyzed with the help of SPSS v16.0 software. The formulas used for computing the stress tolerance indices were furnished below.

**Table 1**

| **Mean Productivity (MP)** | **(DMP in Non Saline Water Irrigated Soil + DMP in Saline Water Irrigated Soil) / 2** | **Rosielle & Hamblin, 1981** |
|---|---|---|
| Genometric Mean Productivity (GMP) | SQRT (DMP in non saline water irrigated soil x DMP in saline water irrigated soil) | Fernandez, 1992 |
| Stress Tolerance Intensity (STIy) | (DMP in non saline water irrigated soil x DMP in saline water irrigated soil) / Sq of DMP in non saline water irrigated soil | Fisher & Maurer, 1978 |
| Stress Tolerance index (STIx) | (DMP in non saline irrigated soil - DMP in Saline water irrigated soil)*100 | Fernandez, 1992 |
| Tolerance index (TOL) | DMP in non saline water irrigated soil - DMP in saline water irrigated soil | Rosielle & Hamblin, 1981 |
| DMP stability index (DSI) | DMP in saline water irrigated soil / DMP in non saline water irrigated soil | Bouslam & Schapaugh, 1984 |

## RESULTS AND DISCUSSIONS

Saline water irrigation significantly reduced most of the growth variables of all the maize hybrids. Higher growth attributes were noted in the maize hybrids irrigated with non saline water (0.6 $dSm^{-1}$). However increasing water salinity ($EC_{iw}$) decreased the plant growth parameters in all the maize hybrids and the degree of reduction varied among the hybrids which might be due to their differential genetic potentials on ionic exclusion and absorption.

**Plant Growth Parameters**

Higher genetic variability in salinity tolerance with respect to different seedling traits such as shoot length, root length, dry weight of all the six maize hybrids were observed. Shoot length was affected significantly with the increase in irrigation water salinity (Table 1) and the rate of reduction in shoot length was higher at 8.9 $dSm^{-1}$ in comparison to non saline water (0.6 $dSm^{-1}$). The order of lesser reduction in shoot length among the maize hybrids was: CO 6 > CO 7 > NK6240 > 900M gold > CO 10 > CO 8. Increasing salinity level decreased the root length of maize hybrids also significantly which ranged between 11.2 to 25.5 cm. Maximum reduction in mean root length was measured in CO 8 (18.6 cm) and minimum was observed in CO 6 (22.7 cm). The reduction in shoot and root length might be due to excessive accumulation of salts in the cell wall and similar reduction in plant growth due to irrigation water salinity was reported by Pessarakli & Kopec (2009).

Dry matter production (DMP) of crops declined with increasing salinity with the per cent reduction varied from 21.2 to 38.7. Higher DMP was recorded in CO 6 (5.40 g) and CO 7 (4.92 g), however, CO 8 registered the lowest DMP (3.73 g). Lesser reduction in DMP due to salinity was observed with CO 6 and CO 7, which indicated their better tolerance to saline water irrigation. Greater reduction in DMP of all maize hybrids at higher water salinity (>8 $dSm^{-1}$) could be attributed to the root zone salinity and sensitivity of maize hybrids to higher irrigation water salinity (Ashraf *et al*., 2008; Ahmadi and Ardekani, 2006). All maize hybrids showed better growth under saline water irrigation upto 3.20 $dSm^{-1}$ (< 12% reduction in DMP). However the maize hybrid CO 6 and CO 7 has maintained its tolerance upto 4.8 $dSm^{-1}$ with less than 15 per cent reduction in DMP, which was same as result published by Prajuabmon *et al*., (2009) who reported greater reduction in shoot length, fresh and dry weight of shoot and relative growth rate of rice under saline water irrigation.

**Stress Tolerant Indices**

The potential of maize hybrids in sustaining salinity of irrigation water was evaluated by determining their tolerance in terms of plant biomass production and stress tolerance indices. Hence, various indices such as stress tolerance index (STIx), Mean productivity (MP), Genometric mean productivity (GMP), DMP stability index (DSI), tolerance index (TOL) and Stress tolerance intensity (STIy) were computed using the dry matter production of all maize hybrids (Table 2&3).

Significant differences in the biomass production and stress tolerance indices were observed among the maize hybrids with different ECiw. Stress tolerance index computed for the maize hybrids based on DMP ranged between 95.8 to 36.9 % and the highest mean STI was observed in CO 6 (78.8 %) followed by CO 7 (75.4%). The result of the present study was in agreement with the results achieved by Giaveno *et al.*, (2007) in screening tropical maize for salt tolerance.

Mean productivity (MP) under different ECiw showed significantly higher variation aong the hybrids and the maximum mean productivity was recorded in CO 6 (5.45) followed by CO 7 (4.96). Increasing irrigation water salinity decreases the mean productivity of different maize hybrids and similar findings was reported by Yokoi *et al.*, (2002). Lesser mean productivity value was recorded in CO 8 (3.73) which indicated its sensitivity to salinity. Genometric mean productivity (GMP) also decreases with increasing salinity and the biomass accumulation was severely affected consequently with increasing salinity. Higher mean genometric productivity was noted in CO 6 (5.44) which was followed by CO 7 (4.95) and minimum GMP was recorded in CO 8 (3.71).

Stress tolerance intensity (STIy) computed for the six maize hybrids revealed significant variation among the maize hybrids. Increasing salinity is accompanied by significant reduction in stress tolerance indices. The highest stress tolerance intensity of 13.1 was observed in CO 6 hybrid followed by CO 7 (11.4) and the lowest stress tolerance intensity was noted in CO 8 (7.69). Similar trend was observed by Yagdi and Sozen, (2009) in maize hybrids under NaCl stress condition.

DMP stability index was computed using the plant DMP values at different ECiw levels and it ranges from 0.37 to 0.96. Increasing ECiw decreases the DSI rate and among the six hybrids, CO 6 (0.79) recorded highest DSI followed by CO 7 (0.75) and the least was obtained with CO8 (0.61). Increasing ECiw level increases the TOL rate with deceasing DMP values and the values varied from 0.51 to 3.04 in 3.2 and 8.9dSm$^{-1}$ respectively. The lowest rate measured with CO 6 (1.38) and highest value of 2.09 was recorded in CO 8.

Correlating the indices computed with the dry matter production of maize hybrids by linear regression confirms that these indices explain 98 to 99 per cent variability in the dry matter production of crops (Figure 1). DMP under different ECiw were positively correlated with STIx, DSI, MP GMP, STIy and the correlation coefficient ($r^2$) values were 0.92, 0.90, 0.88, 0.88 and 0.87 respectively. While significant negative correlation was observed with TOL and DMP ($r^2$ = -0.99) (Table 4). Similar result was found by Sanjay singh *et al*., (2015). As STIx, DSI, GMP, MP and STIy were able to identify crops producing higher dry matter production (Betran *et al*., 2003) even under severe stress condition these indices were found to be more useful in identifying saline water tolerant maize hybrids. Mohammad *et al*., (2010) was found that STIx and DSI were more useful indices to discriminate tolerant hybrids from susceptible one due to their negative correlation with TOL. In this study, hybrid CO 6 followed by CO 7 and NK6240 had the lowest TOL and highest value of other indices therefore these hybrids have low susceptibility even a higher saline water stress condition. Reverse was true in CO 8 and identified as highly susceptible to saline water stress.

## CONCLUSIONS

According to the results, it can be concluded that screening crops at early stage is a convenient and fairly reliable technique for determining differences with respect to salt tolerance. Increasing water salinity significantly reduced the plant growth attributes, biomass production in all maize hybrids while some were tolerant to stress indicating the sufficient genetic variability. Based on the correlation studies it can be concluded that STIx, DSI, MP and GMP were the best indicator for selecting stress tolerance of maize hybrids. It was observed that maize hybrids can grow with minimum DMP reduction (<10 %) upto an irrigation water salinity of 3.2 dSm$^{-1}$. However the hybrids CO 6 and CO 7 were identified as tolerant hybrids for saline water irrigation up to 4.8 dSm$^{-1}$ by producing higher plant growth attributes DMP and stress tolerance indices.

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## APPENDICES

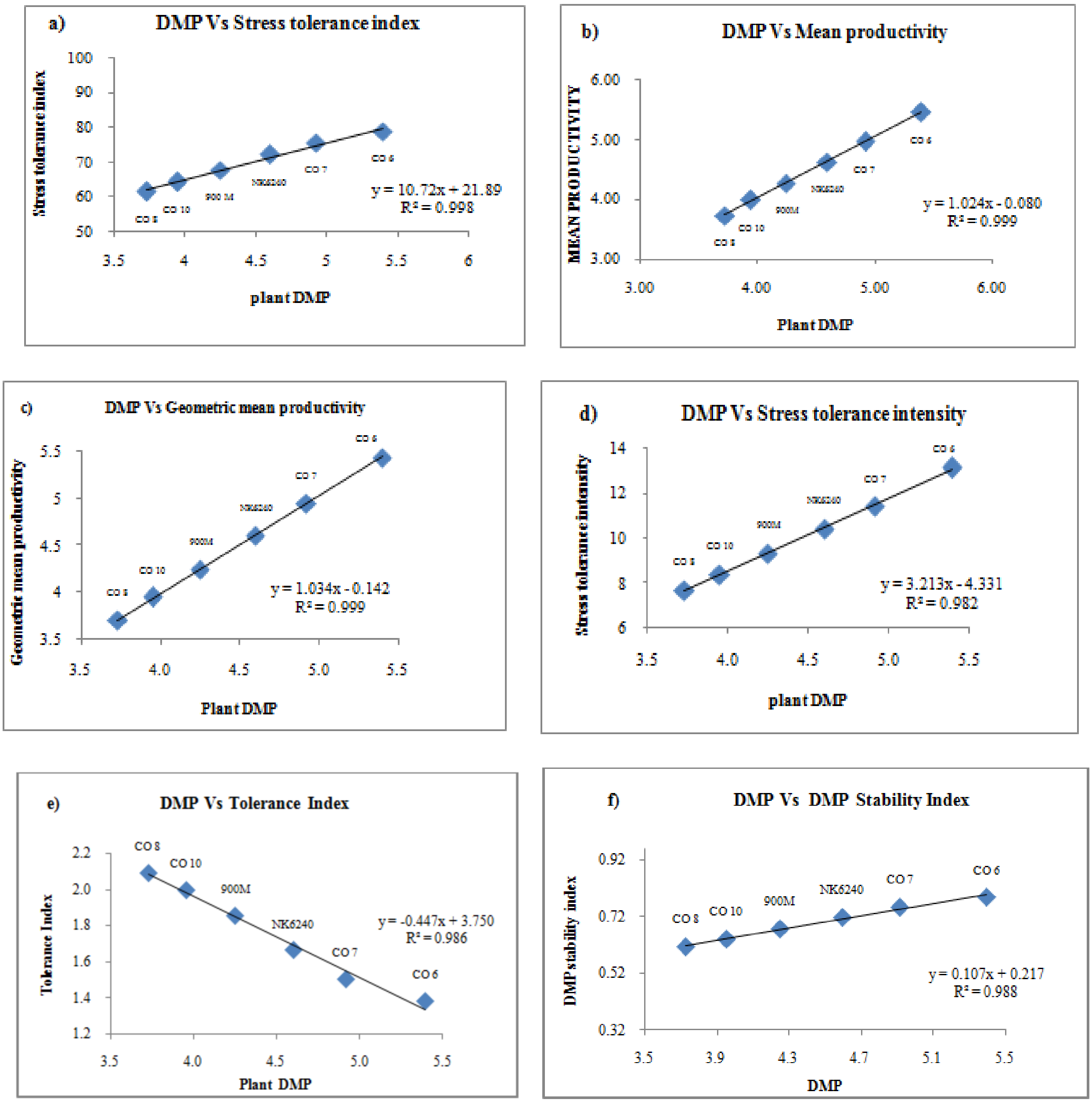


**Figure 1: Correlation between Plants Dry Matter Production and Different Stress Indices a) DMP and Stress Tolerance Index b) DMP and Mean Productivity c) DMP and Geometric Mean Productivity d) DMP and Stress Tolerance Intensity e) DMP Vs Tolerance Index and f) DMP Vs DMP Stability Index**

**Table 1: Effect of Irrigation Water Salinity on Plant Height, Root Length and DMP**

| Maize Hybrids / EC Levels dSm$^{-1}$ | Plant Height | | | | | | Root Length | | | | | | Total DMP (grams) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EC 1 | EC 2 | EC 3 | EC 4 | EC 5 | Mean | EC 1 | EC 2 | EC 3 | EC 4 | EC 5 | Mean | EC 1 | EC 2 | EC 3 | EC 4 | EC 5 | Mean |
| CO 6 | 69.2 | 67.5 | 63.0 | 58.7 | 47.6 | 61.2 | 29.8 | 25.5 | 22.7 | 19.8 | 15.5 | 22.7 | 6.50 | 6.23 | 5.66 | 4.75 | 3.84 | 5.40 |
| CO 7 | 64.0 | 62.5 | 57.8 | 52.3 | 46.9 | 56.7 | 28.7 | 25.0 | 21.9 | 19.4 | 15.2 | 22.1 | 6.12 | 5.67 | 5.20 | 4.23 | 3.36 | 4.92 |
| CO 8 | 60.2 | 55.5 | 49.5 | 39.4 | 30.2 | 46.9 | 26.0 | 22.5 | 18.5 | 14.7 | 11.2 | 18.6 | 5.40 | 4.76 | 3.80 | 2.68 | 1.99 | 3.73 |
| CO 10 | 61.7 | 58.9 | 47.2 | 40.5 | 35.2 | 48.7 | 26.6 | 23.8 | 19.9 | 16.6 | 11.3 | 19.6 | 5.55 | 4.95 | 4.11 | 2.97 | 2.19 | 3.95 |
| NK 6240 | 63.5 | 57.0 | 53.6 | 50.2 | 41.2 | 53.1 | 28.5 | 24.6 | 21.1 | 18.2 | 14.3 | 21.3 | 5.93 | 5.47 | 4.89 | 3.69 | 3.02 | 4.60 |
| 900 M GOLD | 63.7 | 58.5 | 50.7 | 42.1 | 39.8 | 51.0 | 27.3 | 24.1 | 20.6 | 16.9 | 12.3 | 20.3 | 5.74 | 5.10 | 4.43 | 3.39 | 2.61 | 4.25 |
| MEAN | 63.7 | 60.0 | 53.6 | 47.2 | 40.2 | 52.9 | 27.8 | 24.3 | 20.8 | 17.6 | 13.3 | 20.8 | 5.87 | 5.36 | 4.68 | 3.62 | 2.84 | 4.47 |
| | EC | G | ECx G | | | | EC | G | ECx G | | | | EC | G | ECxG | | | |
| SE(d) | 0.48 | 0.52 | 1.18 | | | | 0.21 | 0.24 | 0.53 | | | | 0.31 | 0.34 | 0.77 | | | |
| CD (P=0.05) | 0.96 | 1.05 | 2.35 | | | | 0.43 | 0.48 | 1.07 | | | | 0.63 | 0.69 | 1.55 | | | |

**Table 2: Effect of Irrigation Water Salinity on Stress Tolerance Index, Mean Productivity and Geometric Mean Productivity**

| Maize Hybrids / EC Levels dSm$^{-1}$ | Stress Tolerance Index (STIx) | | | | | Mean Productivity (MP) | | | | | Geometric Mean Productivity (GMP) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EC 2 | EC 3 | EC 4 | EC 5 | Mean | EC 2 | EC 3 | EC 4 | EC 5 | Mean | EC 2 | EC 3 | EC 4 | EC 5 | Mean |
| CO 6 | 95.8 | 87.1 | 73.1 | 59.1 | 78.8 | 6.37 | 5.95 | 5.21 | 4.30 | 5.45 | 6.36 | 5.94 | 5.19 | 4.27 | 5.44 |
| CO 7 | 92.6 | 85.0 | 69.1 | 54.9 | 75.4 | 5.90 | 5.44 | 4.72 | 3.80 | 4.96 | 5.89 | 5.43 | 4.69 | 3.77 | 4.95 |
| CO 8 | 88.2 | 70.4 | 49.6 | 36.9 | 61.3 | 5.08 | 4.28 | 3.24 | 2.34 | 3.73 | 5.07 | 4.25 | 3.19 | 2.31 | 3.71 |
| CO 10 | 89.2 | 74.1 | 53.5 | 39.5 | 64.1 | 5.25 | 4.53 | 3.54 | 2.58 | 3.98 | 5.24 | 4.51 | 3.49 | 2.55 | 3.95 |
| NK 6240 | 92.2 | 82.5 | 62.2 | 50.9 | 72.0 | 5.70 | 5.18 | 4.29 | 3.36 | 4.63 | 5.70 | 5.17 | 4.25 | 3.34 | 4.61 |
| 900 M GOLD | 88.9 | 77.2 | 59.1 | 45.5 | 67.6 | 5.42 | 4.77 | 3.91 | 3.00 | 4.27 | 5.41 | 4.75 | 3.88 | 2.97 | 4.25 |
| MEAN | 91.2 | 79.4 | 61.1 | 47.8 | 69.9 | 5.62 | 5.02 | 4.15 | 3.23 | 4.50 | 5.61 | 5.01 | 4.11 | 3.20 | 4.48 |
| | EC | G | ECxG | | | EC | G | ECxG | | | EC | G | ECxG | | |
| SE(d) | 0.06 | 0.07 | 0.15 | | | 0.06 | 0.07 | 0.14 | | | 0.06 | 0.07 | 0.14 | | |
| CD (P=0.05) | 0.12 | 0.14 | 0.31 | | | 0.12 | 0.14 | 0.29 | | | 0.12 | 0.15 | 0.29 | | |

Irrigation water salinity (dSm$^{-1}$): EC1 = 0.6; EC2= 3.2; EC3 = 4.8; EC4 = 6.7; EC= 8.9 dSm$^{-1}$

**Table 3: Effect of Irrigation Water Salinity on Stress Tolerance Intensity, DMP Stability Index and Tolerance Index**

| Maize Hybrids / EC Levels $dSm^{-1}$ | Stress Tolerance Intensity (STIy) | | | | | DMP stability index (DSI) | | | | | Tolerance Index (TOL) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EC 2 | EC 3 | EC 4 | EC 5 | Mean | EC 2 | EC 3 | EC 4 | EC 5 | Mean | EC 2 | EC 3 | EC 4 | EC 5 | Mean |
| CO 6 | 15.9 | 14.4 | 12.1 | 9.8 | 13.1 | 0.93 | 0.85 | 0.69 | 0.55 | 0.75 | 0.45 | 0.92 | 1.89 | 2.76 | 1.51 |
| CO 7 | 14.0 | 12.9 | 10.5 | 8.3 | 11.4 | 0.96 | 0.87 | 0.73 | 0.59 | 0.79 | 0.27 | 0.84 | 1.75 | 2.66 | 1.38 |
| CO 8 | 11.1 | 8.83 | 6.23 | 4.63 | 7.69 | 0.88 | 0.70 | 0.50 | 0.37 | 0.61 | 0.64 | 1.60 | 2.72 | 3.41 | 2.09 |
| CO 10 | 11.7 | 9.69 | 7.00 | 5.16 | 8.38 | 0.89 | 0.74 | 0.54 | 0.39 | 0.64 | 0.60 | 1.44 | 2.58 | 3.36 | 2.00 |
| NK 6240 | 13.3 | 11.9 | 8.99 | 7.36 | 10.4 | 0.92 | 0.82 | 0.62 | 0.51 | 0.72 | 0.46 | 1.04 | 2.24 | 2.91 | 1.66 |
| 900 M GOLD | 12.2 | 10.6 | 8.13 | 6.26 | 9.31 | 0.89 | 0.77 | 0.59 | 0.45 | 0.68 | 0.64 | 1.31 | 2.35 | 3.13 | 1.86 |
| MEAN | 13.0 | 11.4 | 8.82 | 6.92 | 10.0 | 0.91 | 0.79 | 0.61 | 0.48 | 0.70 | 0.51 | 1.19 | 2.26 | 3.04 | 1.75 |
| | EC | G | ECxG | | | EC | G | ECxG | | EC | EC | G | ECxG | | |
| SE(d) | 0.20 | 0.25 | 0.50 | | | | | | | | | | | | |
| CD (P=0.05) | 0.41 | 0.50 | 1.01 | | | | | | | | | | | | |

Irrigation water salinity ($dSm^{-1}$): EC1 = 0.6; EC2= 3.2; EC3 = 4.8; EC4 = 6.7; EC= 8.9 $dSm^{-1}$

**Table 4: Relationship among Traits Studied in this Investigation**

| Stress Tolerance Indices | DMP | Stix | Stiy | MP | GMP | TOL | DSI |
|---|---|---|---|---|---|---|---|
| DMP | 1 | | | | | | |
| STIx | 0.92** | 1 | | | | | |
| STIy | 0.87* | 0.99** | 1 | | | | |
| MP | 0.88* | 0.99** | 0.99** | 1 | | | |
| GMP | 0.88* | 0.99** | 0.99** | 0.99** | 1 | | |
| TOL | -0.99** | -0.95** | -0.91* | -0.92** | -0.93** | 1 | |
| DSI | 0.90* | 1.00** | 0.99** | 0.99** | 0.99** | -0.95** | 1 |

**Abbreviations**

| | | |
|---|---|---|
| DMP | - | Dry Matter Production |
| STIx | - | Stress tolerance Index |
| STIy | - | Stress tolerance Intensity |
| MP | - | Mean Productivity |
| GMP | - | Geometric Mean Productivity |
| TOL | - | Tolerance index |
| DSI | - | DMP stability index |